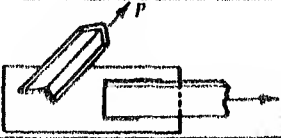

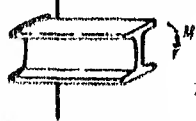





WELDING

Type of Loading	Standard Design Formula	Treating the Weld as a Line
	Primary Welds transmit entire load	
	tension or compression $s = \frac{P}{A}$	$f = \frac{P}{L_w}$
	vertical shear $s = \frac{V}{A}$	$f = \frac{V}{L_w}$
	bending $s = \frac{M}{Z}$	$f = \frac{M}{Z_w}$
	twisting $s = \frac{TC}{J}$	$f = \frac{TC}{J_w}$
	Secondary Welds hold section together — low stress	
	horizontal shear $s = \frac{VAy}{I}$	$f = \frac{VAy}{I_w}$
	torsional horizontal shear $s = \frac{TC}{J}$	$f = \frac{TCt}{J}$

## Primary Welds under Bending and Twisting:

Table (5) shows the properties of the weld schemes treated as a line forming the weld configuration with width =  $b$  and depth =  $d$  together with the position of the neutral axis  $x-x$ .

$b, d, L$  The table demonstrates:

- $eg$  - Section modulus ( $Z_w$ ) for bending
- $Z_w$  - Polar moment of inertia ( $J_w$ ) for torsion.
- $J_w$

Procedure for working the weld size ( $w$  = weld leg):

- (1) Find width ( $b$ ) and depth ( $d$ ) of the weld layout.
- (2) The section modulus ( $Z_w$ ) given in the table are for maximum force at the top as well as the bottom portion of the welded connection.
- (3) For unsymmetrical connections shown in this table, the maximum bending force is at the bottom.
- (4) If there is more than one force applied to the weld, these are found and combined. All forces which are combined (vectorially added) must occur at the same position in the welded joint.
- (5) Standard formula used for weld (treated as a line):

$$f = \frac{Mb}{Z_w} \quad (N/mm)$$

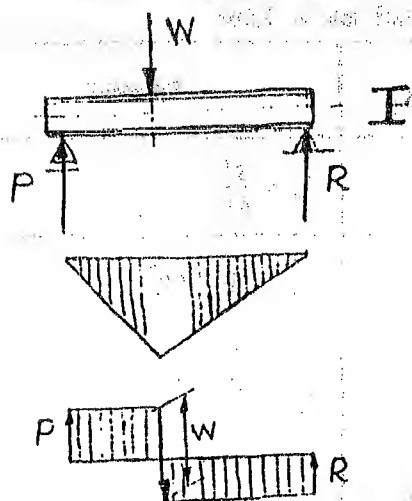
$$f^* = 0.707 \cdot \tau_{all\ weld} \cdot w \quad (N/mm) \quad (\text{see table 7})$$

$$w = \text{weld leg size} = \frac{f}{0.707 \tau_{all\ weld}} \quad (mm)$$

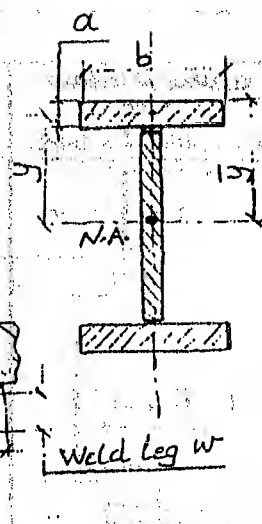
continuous  $w$  should be  $\geq w_{min}$  given in table (3) or find  $\frac{w}{w_{min}} \times 100\%$  and use table (40) to find length and

140. weld size

### Calculation of Secondary Stds.



$$\begin{aligned} I_{\text{whole}} &= \checkmark \\ y &= \checkmark \\ A &= a \cdot b \\ n &= \text{No. of welds} \end{aligned}$$



$$F_s = \frac{P \cdot A \cdot y}{I \cdot n}$$

$$N/\text{mm}, \quad w = \frac{F_s}{0.707 \tau_{\text{all weld}}} \text{ mm, where}$$

$\tau_{\text{all weld}}$  is the value recommended by AWS as shown in table (7),  $w$  is then taken as % of  $w_{\text{min}}$  given in table (3) and from table (10) the welding style selected.

**TABLE 3—Minimum Weld Sizes for Thick Plates (AWS)**

THICKNESS OF THICKER PLATE JOINED t (mm)	MINIMUM LEG SIZE OF FILLET WELD	
	w	mm
to 1/2" Incl. Up to 12.5	3/16"	5
over 1/2" thru 3/4" From 12.5 up to 19	1/4"	6.5
over 3/4" thru 1 1/2" 19 up to 38	5/16"	8
over 1 1/2" thru 2 1/4" 38 up to 57	3/8"	9.5
over 2 1/4" thru 6" 57 up to 152	1/2"	12.5
over 6" more than 152	5/8"	16

Minimum leg size need not exceed thickness of the thinner plate.

Table 5 - Primary Welds Treated as a LINE.

Properties of Weld Treated as a Line		
Outline of Welded Joint $b$ = width $d$ = depth	Bending (about horizontal axis $X-X$ )	Twisting
	$Z_w = \frac{d^2}{6}$	$I_w = \frac{d^3}{12}$
	$Z_w = \frac{d^2}{3}$	$I_w = \frac{d(3d^2 + d^3)}{6}$
	$Z_w = bd$	$I_w = \frac{b^3 + 3bd^2}{6}$
	$Z_w = \frac{4bd + d^2}{6} = \frac{d^2(4bd + d)}{6(2b + d)}$ top bottom	$I_w = \frac{(b + d)^4 - 6b^2d^2}{12(b + d)}$
	$Z_w = bd + \frac{d^2}{6}$	$I_w = \frac{(2b + d)^3}{12} - \frac{b^2(b + d)^2}{(2b + d)}$
	$Z_w = \frac{2bd + d^2}{3} = \frac{d^2(2b + d)}{3(b + d)}$ top bottom	$I_w = \frac{(b + 2d)^3}{12} - \frac{d^2(b + d)^2}{(b + 2d)}$
	$Z_w = bd + \frac{d^2}{3}$	$I_w = \frac{(b + d)^3}{6}$
	$Z_w = \frac{2bd + d^2}{3} = \frac{d^2(2b + d)}{3(b + d)}$ top bottom	$I_w = \frac{(b + 2d)^3}{12} - \frac{d^2(b + d)^2}{(b + 2d)}$
	$Z_w = \frac{4bd + d^2}{3} = \frac{4bd^2 + d^3}{6b + 3d}$ top bottom	$I_w = \frac{d^2(4b + d)}{6(b + d)} + \frac{b^3}{6}$
	$Z_w = bd + \frac{d^2}{3}$	$I_w = \frac{b^3 + 3bd^2 + d^3}{6}$
	$Z_w = 2bd + \frac{d^2}{3}$	$I_w = \frac{2b^3 + 6bd^2 + d^3}{6}$
	$Z_w = \frac{\pi d^2}{4}$	$I_w = \frac{\pi d^3}{4}$
	$Z_w = \frac{\pi d^2}{2} + \pi D^2$	

Courtesy The Lincoln Electric Co.

**TABLE 7—Allowables for Welds—Bridges  
(AWS Bridge)**

Type of Weld	Stress	Steel	Electrode	Allowable
Complete-Penetration Groove Welds	tension compression shear	A7, A373	E60 or SAW-1	Same as $R$
		A36 $\leq 1"$ thick		
		A36 $> 1"$ thick	E60 low-hydrogen or SAW-1	
		A441, A242*	E70 low-hydrogen or SAW-2	
Fillet Welds	shear on effective throat	A7, A373	E60 or SAW-1	$r = 12,400$ psi or $f = 8900$ or lb/in
		A36 $\leq 1"$ thick		
		A36 $> 1"$ thick	E60 low-hydrogen or SAW-1	$r = 14,700$ psi or $f = 10,400$ or lb/in
		A441, A242*	E70 low-hydrogen or SAW-2	
Plug and Slot	shear on effective area	A7, A373, A36 $\leq 1"$ thick	E60 or SAW-1	12,400 psi
		A36 $> 1"$ thick A441, A242*	E60 low-hydrogen or SAW-1	

\* weldable A242

‡ E70 or SAW-2 could be used, but would not increase allowable



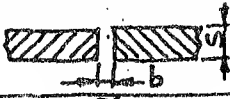


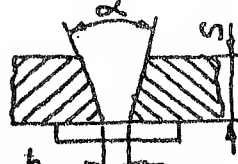
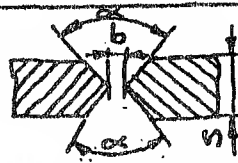

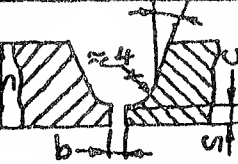


**TABLE 10—Intermittent Welds  
Length and Spacing**

Continuous weld, %	Length of intermittent welds and distance between centers, in.		
75	..	3-4	..
66	..	..	4-6
60	..	3-5	..
57	..	..	4-7
50	2-4	3-6	4-8
44	..	..	4-9
43	..	3-7	..
40	2-5	..	4-10
37	..	3-8	..
33	2-6	3-9	4-12
30	..	3-10	..
25	2-8	3-12	..
20	2-10	..	..
16	2-12	..	..

20 ft  
12 in

Extracted from DIN 8551 - Jan 1959

Edge preparation for open arc welding of steel by hand

No	S mm	Deposition method	Type of Weld	Symbol	Edge Form Sectional view	$\alpha$ or $\beta$ degrees	Gap b(mm)	C mm	h mm
1	up to 2	From one side Only	Flanged butt weld			—	—	—	—
2	3	One side	Square butt weld			—	$\approx s$	—	—
	5	Both sides				—	$\approx \frac{s}{2}$	—	—
3	3 to 20	One side	Single Vee Butt Weld	V		$\approx 60^\circ$	$\approx 2$	—	—
	5 to 20	Two sides							
4	Over 10	From One Side (use back plate)	Double bevel Butt Weld			$\approx 10^\circ$	6 to 10	—	—
5	From 16-40	From both Sides	Double Vee	X		$\approx 60^\circ$	$\approx 2$	—	$\frac{s}{2}$
		2/3 Double Vee							$\approx \frac{s}{3}$
6	8-20	From both Sides	Single Vee with root face	Y		$\approx 60^\circ$	0 to 2	2 to 4	—
7	Over 16	From One Side Only	Single U	Y		$\approx 10^\circ$	$\approx 2$	$\approx 2$	—
		From both Sides					0 to 2	$\approx 3$	—
8	Over 30	From both Sides	Double U			$\approx 10^\circ$	0 to 3	$\approx 3$	$\approx \frac{s}{2}$

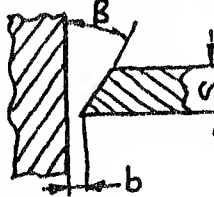
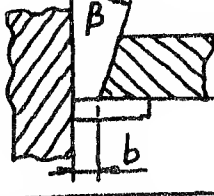
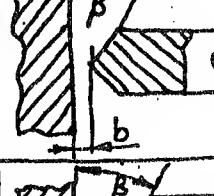
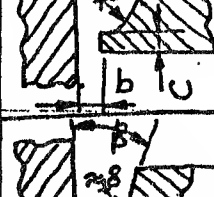
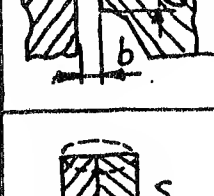
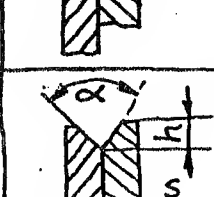
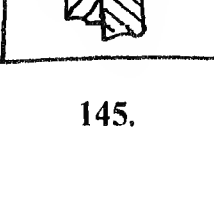
No	S mm	Deposition method	Type of Weld	Symbol	Edge Form Sectional view	$\alpha$ or $\beta$ degrees	Gap b (mm)	C (mm)	h (mm)
9	3 to 16	From One Side	Half Single Vee	V		45° to 60°	0 to 3	—	—
	6 to 16	From Both Sides							
10	Over 16	From One Side	Single - bevel			30° to 15°	6 to 10	—	—
11	16 to 40	From both Sides	Double bevel	K		45° to 60°	0 to 2	—	—
12	Over 16	From One Side	single J	J		$\approx 20^\circ$	$\approx 2$	$\approx 2$	—
		From both Sides							
13	Over 30	From both Sides	Double J	K		$\approx 20^\circ$	$\approx 2$	$\approx 2$	—
14	Over 3	From One Side	Square edges	III		—	—	—	—
15	Over 4	From One side	Beveled edges	M		$\approx 60^\circ$	—	—	5 to 1.2 S

Table 11. Mechanical Properties of Some Construction Steels\*

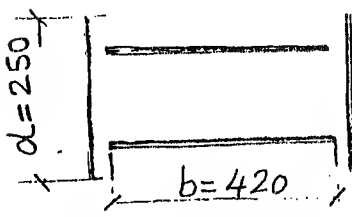
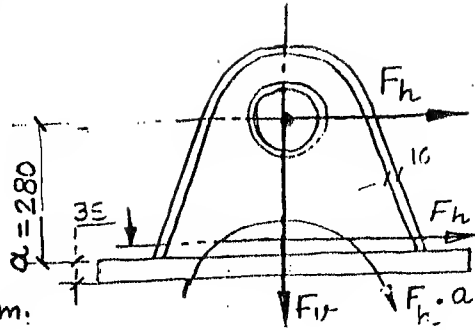
Steel designation	Thickness range, mm(in)	Yield point, min		Tensile strength		Elongation in 200 mm (8 in) min, %	Suitability for welding
		MPa	1,000 lb/in <sup>2</sup>	MPa	1,000 lb/in <sup>2</sup>		
Structural carbon-steel plates							
ASTM A36	All thicknesses	228	33	414-517	60-75	21	No
	To 100 mm (4 in), incl.	221	32	400-517	58-75	21	Yes
	To 100 mm (4 in), incl.	248	36	400-552	58-80	20	Yes
Low- and intermediate-tensile-strength carbon-steel plates							
ASTM A283 (structural quality)	All thicknesses	165	24	310	45	28	Yes
	All thicknesses	186	27	345	50	25	Yes
	All thicknesses	207	30	379	55	22	Yes
	All thicknesses	228	33	414	60	20	Yes
Carbon-silicon steel plates for machine parts and general construction							
ASTM A284							
Grade A	To 305 mm (12 in)	172	25	345	50	25	Yes
Grade B	To 305 mm (12 in)	189	27	379	55	25	Yes
Grade C	To 305 mm (12 in)	145	21	414	60	21	Yes
Grade D	To 200 mm (8 in)	145	21	414	60	21	Yes
Carbon-steel pressure-vessel plates							
ASTM A285							
Grade A	To 50 mm (2 in)	165	24	303-379	44-55	27	Yes
Grade B	To 50 mm (2 in)	186	27	345-414	50-60	25	Yes
Grade C	To 50 mm (2 in)	207	30	379-448	55-65	23	Yes
Structural steel for locomotives and cars							
ASTM A118							
Grade A	All thicknesses	228	33	414-496	60-72	21	No
Grade B	All thicknesses	186	27	345-427	50-62	24	No
Grade C	All thicknesses	179	26	331-400	48-58	26	No
Structural steel for ships							
ASTM A131							
Grade A	To 13 mm (1/2 in)						
Grade B	To 25 mm (1 in)						
Grade C	To 50 mm (2 in)	221	32	400-490	58-71	21	No
Grade E	To 50 mm (2 in)						
Grade D	To 50 mm (2 in)						
Grade F	To 50 mm (2 in)						
High-strength low-alloy steel plates							
ASTM A242	To 19 mm (3/4 in), incl.	345	50	485	70 min	18	Yes
ASTM A421	Over 19 to 18 mm (3/4 to 1 1/4 in), incl.	315	46	460	67 min	18	No
ASTM A501	Over 38 to 102 mm (1 1/2 to 4 in), incl.	290	42	435	63 min	18	Yes
ASTM A588	To 102 mm (4 in), incl.	345	50	485	70	18	Yes



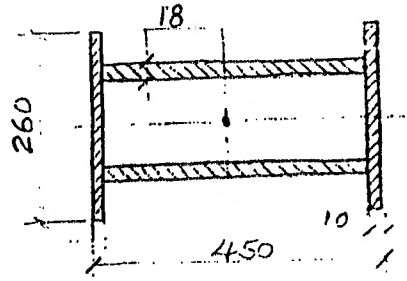
## Primary Weld

Example:

$$\begin{aligned} F_v &= 1254 \text{ kN} \\ F_h &= 151.5 \text{ kN} \\ a &= 280 \text{ mm} \\ \therefore M_k &= 151.5 \times 280 \text{ N.m.} \end{aligned}$$



Lines of welds.



$$\frac{Z_{w1}}{\frac{d^2}{3}} + \frac{Z_{w2}}{b \cdot d} = \frac{Z_{w1} + Z_{w2}}{b \cdot d}$$

$$f_{\text{binding}} = \frac{151.5 \times 280 \times 1000}{\frac{250^2}{3} + (420 \times 250)} = 337 \text{ N/mm}$$

$f_v = 6$

$$f_{\text{shear}} = \frac{151.5 \times 1000}{2(420 + 250)} = 113 \text{ N/mm}$$

$$f_{\text{resultant}} = \sqrt{(337)^2 + (113)^2} = 356 \text{ N/mm}$$

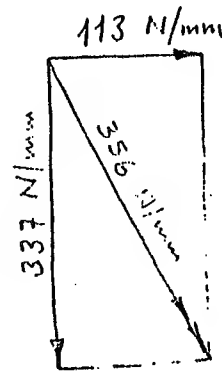
$$f^* = 0.707 \tau_{\text{all weld}} \cdot w$$

$$w = \frac{356}{0.707 \times 85} = 4.2 \text{ mm}$$

Parent metals: 35 max, 10 mm min.

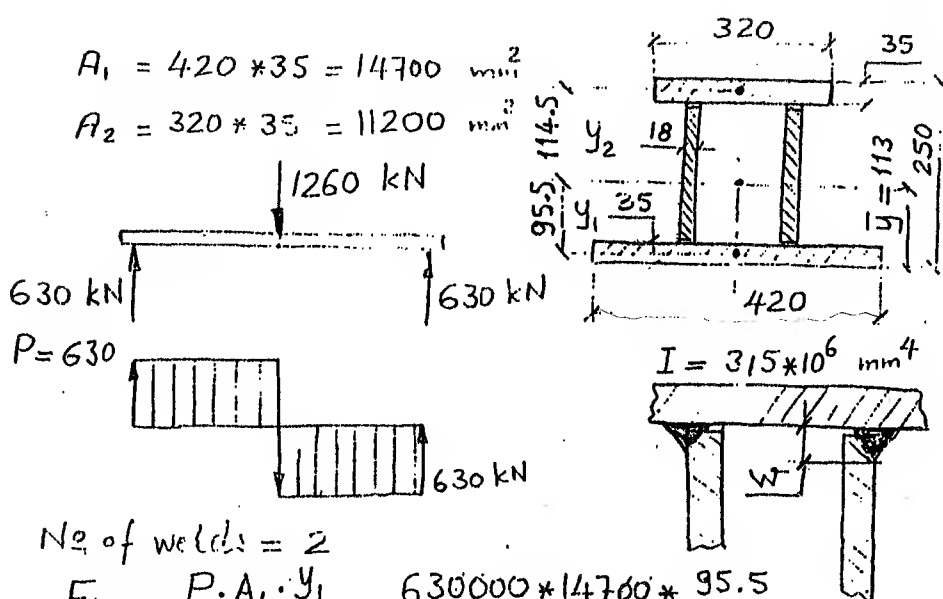
$$\therefore w_{\text{min}} \geq 8 \text{ mm} < 10 \text{ mm.}$$

Continuous weld leg = 8 mm.



### Secondary Weld:

Example: Sec. X-X in drawing D<sub>3</sub> (see Sec. 6)



No. of welds = 2

$$F_{S1} = \frac{P \cdot A_1 \cdot y_1}{I \cdot n} = \frac{630000 \cdot 14700 \cdot 95.5}{315 \cdot 10^6 \cdot 2} = 1.40 \cdot 10^3 \text{ N/mm}$$

Table 7

$$\tau_{\text{all weld}} = 12400 \text{ psi} = 85.50 \text{ N/mm}^2$$

$$\therefore w_1 = \frac{1400}{0.707 \cdot 85.50} = 23 \text{ mm} \quad \text{Web thickness}$$

➔ If No. of welds = 4,  $w_1 = 12 \text{ mm}$

Also:

$$F_{S2} = \frac{630000 \cdot 11200 \cdot 114.5}{3.15 \cdot 10^6 \cdot 2} = 128 \cdot 10^3 \text{ N/mm}$$

$$w_1 = \frac{128000}{0.707 \cdot 85.50} = 21 \text{ mm} > \text{Web thickness}$$

Note:

if  $\tau_{\text{all weld}} = 101.36 \text{ N/mm}^2$  (E60 or SAW1)

$$\therefore w_1 = \frac{1400}{0.707 \cdot 101.36} = 19.5 \text{ mm}$$

$$\& w_2 = \frac{1220}{0.707 \cdot 101.36} = 18 \text{ mm}$$

\*The section X-X in strength calculations was found to be highly stressed and its light was changed to 300 mm

Use Welding electrode.

E70 or SAW2 without changing

$\tau_{\text{all}} = 85.50 \text{ N/mm}^2$

Table 14-1

AMERICAN WELDING SOCIETY



Basic Welding Symbols and Their Location Significance								
Location Significance	Fillet	Plug or Slot	Spot or Projection	Seam	Beck or Beeking	Surfacing	Scarf for Brazed Joint	Flange Edge
Arrow Side								
Other Side						Not used		
Both Sides		Not used	Not used	Not used	Not used	Not used		Not used
No Arrow Side or Other Side Significance	Not used	Not used			Not used	Not used	Not used	Not used
Supplementary Symbols Used with Welding Symbols								
Convex Contour Symbol				Weld-All-Around Symbol				
Convex contour symbol indicates face of weld to be finished to convex contour				Weld-all-around symbol indicates that weld extends completely around the joint				
Joint with Backing		Joint with Spacer		Melt-Thru Symbol				
With groove weld symbol		With modified groove weld symbol		Any applicable weld symbol				
Note: Material and dimensions of backing as specified		Double-bevel groove		Note: Material and dimensions of spacer as specified		Melt-thru symbol is not dimensioned (except height)		
Flush Contour Symbol				Multiple Reference Lines				
Flush contour symbol indicates face of weld to be made flush. When used without a finish symbol, indicates weld without subsequent finishing				First operation shown on reference line nearest arrow				
				Second operation, or supplementary data				
Finish symbol (user's standard) indicates method of obtaining specified contour but not degree of finish				Third operation, or test information				
Field Weld Symbol		Complete Penetration		Location of Elements of a Welding Symbol				
Field Weld symbol indicates that weld is to be made at a place other than that of initial construction		Indicates complete penetration regardless of type of weld or joint preparation		Finish symbol				
				Contour symbol				
				Groove angle; included angle of countersink for plug welds				
				Length of weld				
				Pitch (center-to-center spacing) of welds				
				Field weld symbol				
				Arrow connecting reference line to arrow side member of joint				
				Weld-all-around symbol				
				Reference line				
				Elements in this area remain as shown when tail and arrow are reversed				
				Number of spot or projection welds				

# STANDARD WELDING SYMBOLS

Basic Welding Symbols and Their Location Significance								
Flange	Groove							Location Significance
Corner	Square	V	Bevel	U	J	Flare-V	Flare-Bevel	
								Arrow Side
								Other Side
Not used								Both Sides
Not used		Not used	Not used	Not used	Not used	Not used	Not used	No Arrow Side or Other Side Significance
Typical Welding Symbols								
Spot Welding Symbol			Square-Groove Welding Symbol			Flare-V and Flare-Bevel-Groove Welding Symbols		
<p>Depth of filling in inches (omission indicates filling is complete)</p> <p>Orientation, location and all dimensions other than depth of filling are shown on the drawing</p>			<p>Omission of size indicates complete joint penetration</p> <p>Root opening</p>			<p>Root opening</p> <p>Size is considered as extending only to tangent points</p> <p>Root opening</p>		
Plug Welding Symbol			Chain Intermittent Fillet Welding Symbol			Edge- and Corner- Flange Welding Symbols		
<p>Included angle of countersink</p> <p>Pitch (distance between centers) of welds</p> <p>Depth of filling in inches (omission indicates filling is complete)</p> <p>Size (diameter of hole at root)</p>			<p>Size (length of leg)</p> <p>Pitch (distance between centers) of increments</p> <p>Length of increments</p>			<p>Radius</p> <p>Size of weld</p> <p>Height above point of tangency</p>		
Backgouging Welding Symbol			Back or Backing Welding Symbol			Surfacing Welding Symbol Indicating Built-up Surface		
<p>Second reference line used for back gouging and welding as a second operation</p> <p>Total effective throat not to exceed thickness of member</p>			<p>Any applicable single groove weld symbol</p>			<p>Size (height of deposit)</p> <p>Omission indicates no specific height desired</p> <p>Orientation, location and all dimensions other than size are shown on the drawing</p>		
Fillet or Upset Welding Symbol			Staggered Intermittent Fillet Welding Symbol			Single-V Groove Welding Symbol Indicating Root Penetration		
<p>No arrow side or other side significance</p>			<p>Size (length of leg)</p> <p>Pitch (distance between centers) of increments</p> <p>Length of increments</p>			<p>Size</p> <p>Depth of preparation</p> <p>Effective throat</p> <p>Root opening</p> <p>Groove angle</p>		
Spot Welding Symbol			Double-Bevel-Groove Welding Symbol			Projection Welding Symbol		
<p>Size (diameter of weld) Strength (in lb per weld) may be used instead</p> <p>Process reference must be used to indicate process desired</p> <p>Number of welds</p> <p>Pitch (distance between centers) of weld</p>			<p>Arrow points toward member to be prepared</p> <p>Root opening</p> <p>Groove angle</p>			<p>Projection welding reference must be used</p> <p>Pitch (distance between centers) of welds</p> <p>Number of welds</p>		
Seam Welding Symbol			Double-Fillet Welding Symbol			Welding Symbols for Combined Welds		
<p>Length of welds or increments</p> <p>Omission indicates that weld extends between abrupt changes in direction or as dimensioned</p> <p>Size (width of weld) Strength (in lb per linear inch) may be used instead</p> <p>Pitch (distance between centers) of increments</p> <p>Process reference must be used to indicate process desired</p>			<p>Size (length of leg)</p> <p>Specification, process, or other reference</p> <p>Length</p> <p>Omission indicates that weld extends between abrupt changes in direction or as dimensioned</p>			<p>1/8</p> <p>5/16</p> <p>1/4</p>		
Basic Joints--Identification of Arrow Side and Other Side of Joint						Process Abbreviations		
Lap Joint			Edge Joint			Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table A, Designation of Welding and Allied Processes by Letters, of AWS 2.4-79, 71.		
<p>Other side member of joint</p> <p>Arrow of welding symbol</p> <p>Arrow side member of joint</p>			<p>Arrow side of joint</p> <p>Arrow of welding symbol</p> <p>Joint</p>					
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